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SICKNESS ABSENCE, DISABILITY PENSION, AND PERMANENT MEDICAL IMPAIRMENT AFTER A CAR CRASH

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THESIS FOR LICENCIATE DEGREE

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ABSTRACT

Background: Road traffic injuries constitute a major public health problem worldwide. Permanent medical impairment (PMI) is used as a measure of seriousness of injuries in Sweden. There is little knowledge on consequences of road traffic injuries in terms of sickness absence (SA), disability pension (DP), and PMI as well as on associations between PMI and DP.

Aim: The overall aim of this thesis was to gain knowledge on SA, DP, and PMI among individuals injured in a passenger car crash, in general and in specific groups.

Methods and materials: Two exploratory studies using data linked from Swedish nationwide registers were conducted. Study I was a population-based cross-sectional cohort study. It included all individuals living in Sweden, aged 16-64 years, with in- or specialized out-patient healthcare in 2010 due to injury from a new passenger car crash (n=9427). The study investigated already ongoing SA/DP and new SA at the time of the crash. Study II was a prospective cohort study of injured car occupants aged 17-62 years, reported to the Swedish insurance company Folksam Insurance Group during 2001-2013 (n=64,007). The cohort was followed up two years after the crash date regarding SA, DP, and PMI. In both studies, only SA spells >14 days were considered, and descriptive statistics and logistic regressions, to calculate odds ratios (OR) and 95% confidence intervals (CI), were conducted.

Results: In Study I, 9% were already on SA or DP at the time of the crash; of the others, 10% had a new SA spell. Injury type was the factor with the highest association with having new SA. Injuries to the spine and spinal cord was the injury type most likely to result in a new SA spell, compared with the reference group: sprain of the cervical spine (ages 16-44; OR: 6.32; CI: 4.42-9.05. Ages 45-64; OR: 17.32; CI: 9.85-30.48). Among the younger (16-44 years), injuries to the lower extremities was the injury type with the second highest OR: 5.64; CI: 4.08-7.81, while among 45-64 year olds, the second highest OR was found for traumatic brain injury of other type than concussion (OR: 14.68; CI: 5.80-37.17). In study II, 13% were already on SA or DP at the time of the crash. At follow-up two years after the crash, 7% among those not already on SA/DP at the time of the crash were on SA and 2% on DP. Furthermore, 8% of the total cohort had a determined PMI. The proportion on DP at follow-up was low among those with no or low PMI, but higher with increasing PMI. Sickness absence status at the time of the crash, and PMI grade were the factors most strongly associated with DP at two years after the crash. The factor most strongly associated with PMI was the model year of the car. The older the car, the higher risk of PMI. Occupants injured in cars with model year ≤ 1990 were most likely to have a PMI, compared to the reference group with model years 2006-2010 (OR: 3.36; CI: 2.67-4.23).

Conclusion: Proportions for which the car crash led to a new SA spell varied greatly with type of injury. Being on DP two years after the crash was highly associated with already being on SA at the time of the crash. Thus, both injury type and prevalent SA are important factors to consider when studying SA and DP after a car crash. Higher grades of PMI were associated with higher DP rates among those injured. These findings indicate that both DP and PMI can be used to measure long-term effects of road traffic injuries.

LIST OF SCIENTIFIC PAPERS

- I. Elrud, R., Stigson, H., Ohlin, M., Alexanderson, K., Kjeldgård, L., Friberg, E. Sickness Absence among Passenger Car Occupants following a Crash. International Research Council on Biomechanics of Injury (IRCOBI) Conference proceedings 2017
- II. Elrud, R., Friberg, E., Alexanderson, K., Stigson, H. Disability pension and permanent medical impairment among 64,000 injured car occupants of working ages; a two-year prospective cohort study. *In manuscript*.

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LIST OF ABBREVIATIONS

AIS	Abbreviated Injury Scale
CI	Confidence interval
DP	Disability pension
ICD	International Classification of Diseases
LISA	Longitudinal Integration Database for Health Insurance and Labour Market Studies
MAIS	Maximum Abbreviated Injury Scale
MiDAS	Micro Data for Analysis of the Social insurance
OR	Odds ratio
PMI	Permanent medical impairment
RPMI	Risk of permanent medical impairment
SA	Sickness absence

1 BACKGROUND

Road traffic injuries are a major public health problem in countries around the world. The World Health Organization estimated road traffic crashes to be the cause of 1.2 million deaths, and up to 50 million individuals being non-fatally injured globally, in 2004 (1). With an increasing number of vehicles on the roads around the world, primarily due to increased motorization, road traffic accidents are predicted to be the seventh leading cause of burden of disease in 2030 (2). Low- and middle income countries are more severely affected than high-income countries (1, 3). Road traffic injuries affect individuals of working ages to a high extent, half of all casualties worldwide are between 15 and 44 years old, while in high-income countries, the mortality rate is the highest for the age group 15-29 years old (1). Interventions to prevent road traffic injuries have been undertaken, mainly in high-income countries. These have in many cases been successful in decreasing the number of road traffic casualties. In many countries in western Europe, the number of deaths have declined since the beginning of the 1970 (4). Between 1991 and 2015, the number of fatalities in road traffic per 100,000 inhabitants declined from 16.1 to 5.2 in the European Union, and from 8.7 to 2.7 in Sweden (**Figure 1**) (5). The main part of the reduction in Sweden is due to fewer fatalities among car occupants (6). From around 350 fatally injured car occupants per year in the early 2000s, to 122 in 2014 (5). A probable reason for the successful development in Sweden is the road traffic safety policy Vision Zero, adopted by the Swedish parliament in 1997 (7-9). It is based on the ethical principle that fatalities and serious injuries within the road traffic system are unacceptable. Serious injury is described as “those injuries where the victim does not physically recover within a certain period of time” (10). The vision of a road transport system free from serious health losses, has been the guiding principle for road safety in Sweden and the approach has arguably been successful (10). The concept of Vision Zero has, since it was introduced in Sweden, also been adopted by several other countries and local authorities (11-18).

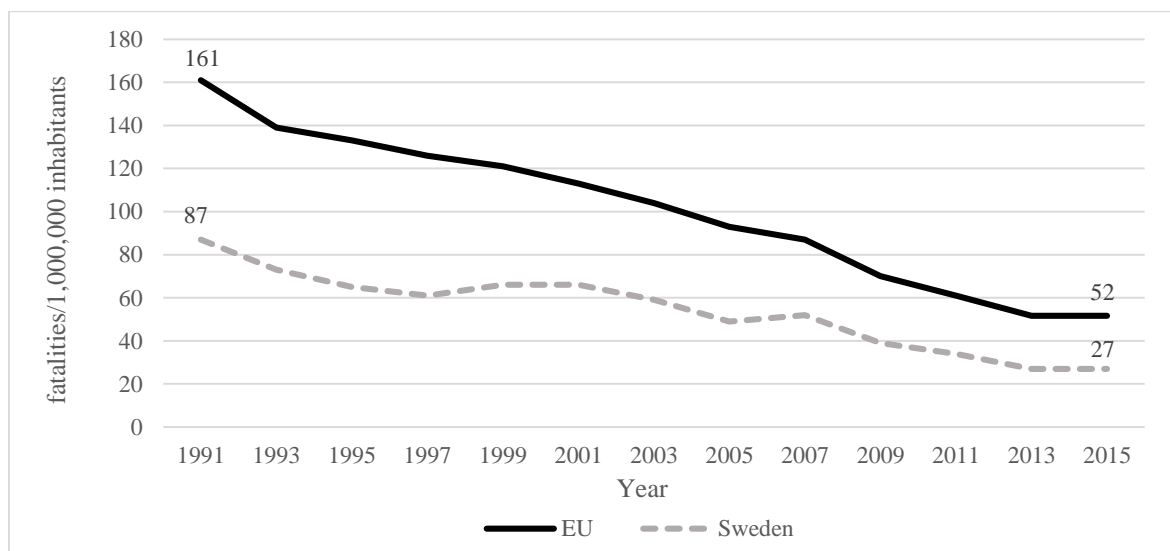


Figure 1. Road traffic fatalities per 1,000,000 inhabitants in the European Union (EU) and Sweden 1991-2015.

Source: Community database on Accidents on the Roads in Europe (CARE) (5).

As the number of deaths decreases, the focus among actors and stakeholders on a policy level, have shifted towards preventing injuries, which reflects in traffic safety policy. In Sweden, the current goal set in 2009 by the Parliament is to reduce the number of fatalities by half, and the number of serious injuries by 25% between 2007 and 2020 (19). In the 2030 Agenda for Sustainable Development, adopted by the United Nations in 2015, the goal set is to reduce road traffic deaths and injuries by 50% by 2020 (20). The European union has beyond the 2020 goals, also set a target to halve the number of serious injuries from 2020 to 2030 (21). However, the number of injuries have in most countries not seen a similar decrease as fatalities (19, 22).

To create a sustainable road transport system, in which the targets regarding not only fatalities but also injuries can be met, definitions of health and what an unacceptable health loss is has to be made.

1.1 THE CONCEPT OF HEALTH

Health has been defined in many ways, seen from different perspectives. A distinction between two main theories of health has been made (23, 24). On the one side, health can be seen from an exclusively biomedical perspective, such as in the biostatistical theory presented by Boorse, in which health is the absence of disease, defined as absence of impairments or limitations to the biological functional ability of an individual (25). On the other side, health can be seen from a holistic perspective, where health is related to the quality of life and wellbeing of an individual, e.g., in terms of the ability to perform actions and achieve essential goals (23). According to this theory, disease does not exclude health, even though it is defined as “a state or process which tends to reduce its bearers health” (23). The previous definition of health used by the World Health Organization belongs to the holistic theories, and is defined as “a state of complete physical, social, and mental wellbeing, and not merely the absence of disease and infirmity” (26). A more contemporary definition is “Health itself should be seen as a resource and an essential prerequisite of human life and social development rather than the ultimate aim of life. It is not a fixed end-point, a “product” we can acquire, but rather something ever changing, always in the process of becoming” (27).

1.2 MEASURING/ASSESSING HEALTH LOSS

1.2.1 Assessment of injuries based on available data

Traditionally, road safety is measured using police-reported deaths and severe injuries, i.e., recorded shortly after a crash (28). In many countries, the police records injury severity on three levels, fatality, serious injury (sometimes defined as hospitalized for >24 hours), and slight injury (29, 30). Several studies have shown that police records do not reflect the true injury outcome and that hospital data are more relevant to use (31, 32). As a complement to fatalities, the Swedish Transport Administration (STA) is, therefore, using nationwide patient hospital data for monitoring and predicting the development towards a safer road safety environment.

In hospital data, classification systems are commonly used to describe the nature of injury from a biomedical perspective of health. The International Classification of Diseases (ICD) is one such classification system used for clinical and epidemiological purposes to classify disease and other health problems into diagnosis codes (33). Another classification commonly used to describe the nature of traffic injury is the Abbreviated Injury Scale (AIS). It defines the injury by type, location, and severity. The severity score is based on the direct

threat to life that the injury constitutes, and is categorised on a 6-point scale, where a minor injury is classified as 1 and maximal severity as 6 (34). Maximum AIS (MAIS) is the highest AIS score of an individual with multiple injuries.

1.2.2 Definitions of serious injury

In order to achieve the road safety goals that have been set up internationally and nationally, different definitions of serious injuries have been suggested. The International Traffic Safety Data and Analysis Group (IRTAD) suggests MAIS3+ as the threshold for when an individual is to be considered seriously injured, but recognizes the need to study other types of consequences, e.g., lifelong disability (35). Injuries that were initially life threatening may later heal without any long-term consequences, while injuries that did not initially pose a threat to life may result in permanent health consequences (36-38). In order to get a more comprehensive picture of consequences of injuries, it is necessary to assess consequences also from other perspectives.

Furthermore, traffic crashes are one of the leading causes of impairment and reduction of productive years among the population (1).

The objective level of impairment among individuals with traffic injury is usually not known. To quantify such impairments, predictions are often made. Several methods have been developed to predict injury impairment using available data, such as the Injury Impairment Scale, Functional Capacity Index (39, 40), and the Risk of permanent medical impairment (RPMI) (38).

Within the above mentioned Vision Zero, a serious injury is defined as one resulting in unacceptable health loss. To reflect that, the Swedish government has, therefore, since 2008 broadened the definition of serious injuries to include long-term consequences of injuries. This is defined as injuries with a RPMI of $\geq 1\%$ (41). The RPMI estimates the risk of permanent medical impairment (PMI) based on loss of physical and/or mental function (38). Permanent medical impairment is a set of grading rules used by Swedish insurance companies to assess medical impairment caused by injury (42). It defines injury from a medical perspective, assessing long-term impairment strictly from a biomedical perspective. Most European countries have similar rules (42). Grading is conducted by consultant physicians, in cases where injured claimants have not recovered within a year. All medical records from before and after the crash are used in the assessment, where a degree of impairment based on the reduction in function caused by the injury is determined. If an injured occupant receives multiple diagnoses that result in medical impairment, a cumulative value of impairment is set. The impairment grade can be between 1 and 99%. Traffic injury causing permanent impairments are compensated in accordance to PMI grade through the mandatory motor vehicle insurance (43). This is a third-party liability insurance compensating injuries of anyone involved in a crash with the motor vehicle, both occupants of the insured vehicle and individuals outside of the vehicle.

With the RPMI $\geq 1\%$ definition of serious injury, the number of seriously injured in road traffic in Sweden is an estimation based on the registered injury diagnosis and the corresponding RPMI (44). It has been found that almost 10% of car occupants with a minor injury, according to the AIS scale, have a determined PMI (38). As can be seen in **Table 1**, for some body regions, injuries with low AIS scores have a quite high RPMI at the $\geq 1\%$ level. For injuries to the upper extremities, lower extremities, or cervical spine, around 17% of injuries result in a RPMI of $\geq 1\%$.

Injuries to the cervical spine is the injury type with the largest number of injuries resulting in PMI, injuries to the upper and lower extremities, however, have the highest RPMI (36, 37). Women generally have higher RPMI when injured than men, mainly due to whiplash injuries (36). Further, older age is associated with higher RPMI (36) and rollover is the crash impact direction associated with the highest RPMI (37). Modern car safety features have been found to reduce the injury (45-47), and the proportion of injured occupants with PMI have been found lower in more modern cars compared to older (48).

However, there is a lack of knowledge regarding to what extent RPMI reflects consequences of traffic injury measured in other terms of health loss. Furthermore, there are no published studies investigating how such health loss corresponds to different grades of RPMI.

Table 1. Risk of Permanent Medical Impairment (RPMI) on the $\geq 1\%$ and $\geq 10\%$ level respectively, stratified by Abbreviated Injury Scale (AIS) level and body region. Numbers in percent. Source: Malm et al. (38).

Body region	RPMI $\geq 1\%$					RPMI $\geq 10\%$				
	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5
Head	8.0	15	50	80	100	2.5	8	35	75	100
Cervical Spine	16.7	61	80	100	100	2.5	10	30	100	100
Face	5.8	28	80	100	100	0.4	6	60	60	n.a.
Upper Extremity	17.4	35	85	100	n.a.	0.3	3	15	100	n.a.
Lower Extremity and Pelvis	17.6	50	60	60	100	0.0	3	10	40	100
Thorax	2.6	4.0	4	30	30	0.0	0	0	15	15
Thoracic Spine	4.9	45	90	100	100	0.0	7	20	100	100
Abdomen	0.0	2.4	10	20	20	0.0	0.0	5	5	5
Lumbar Spine	5.7	55	70	100	100	0.1	0.1	6	100	100
External (Skin) and Thermal Injuries	1.7	20	50	50	100	0.03	0.03	50	50	100

n.a.: not applicable (injuries in these body regions do not result in this severity grade)

1.3 CONSEQUENCES OF TRAFFIC INJURIES FOR INJURED CAR OCCUPANTS

Consequences of traffic injuries can, of course, be studied on different structural levels. In this thesis, consequences for the injured car occupant is considered, regarding sickness absence (SA), disability pension (DP), and permanent medical impairment (PMI).

To understand traffic injuries and their consequences, and to be able to make decisions and prioritizations on effective preventive measures, knowledge has to be generated about different types of consequences, and how different methods to measure this could provide information on consequences from different perspectives. There is currently a lack of consensus on how consequences should be measured, with different methods being used internationally as well as nationally.

1.3.1 Sickness absence and disability pension

Road traffic injuries may result in different types of social and economic consequences for the individual. One important such consequence is that it might lead to work incapacity and thus loss of income from work (49, 50).

Disease and injury may cause a reduction of an individual's work capacity. Many countries have social security systems that can provide compensation for loss of income in the case of such work incapacity, where an individual may qualify for temporary benefits in case of short-term work incapacity or more long-lasting benefits in case of permanent or long-term work incapacity (49, 51-53).

The social insurance systems differ somewhat from country to country, also with regards to rules of compensation of income loss due to work incapacity, e.g., requirements and qualifications for compensation, compensation levels, and duration of compensation (49, 53). Also, different terms have been used in different countries and during different periods for similar concepts. Short-term work incapacity due to disease or injury is called different names, such as sickness absence, sick-leave, work disability, or compensated time off work. Permanent or long-term work incapacity can be called disability pension, disability benefits, incapacity benefits, disability insurance, early pension on medical grounds, incapacity pension, incapacity retirement, medical retirement, ill health retirement, work disability pension. To facilitate international comparisons, the Organisation for Economic Co-operation and Development (OECD) have included all spells of sickness benefits longer than two years under the term disability benefits, here called disability pension (53).

In this thesis, the concepts sickness absence (SA) and disability pension (DP) are used, with the definition stated later in this section. With a holistic perspective on health, where it is a resource and related to the ability to achieve essential goals, work incapacity may be an appropriate measure of consequences of health loss. Work incapacity and compensation thereof are very complex issues. The prevalence and incidence of SA and DP are influenced by many factors, not least changes in social insurance regulations (49). Both SA and DP have been found associated with sociodemographic factors such as age, sex, level of education, and country of birth (54, 55). There are, however, few studies on SA as a consequence of traffic injuries, and even fewer on DP. These concepts are also operationalized in very different ways in the studies, which makes comparison difficult. The few published studies, are often restricted to specific diagnoses or only include severe injuries. Furthermore, often studies do not exclude individuals not at risk of SA or DP (e.g., those not eligible due to age, not being insured, or already being on SA or DP). Further, some studies use self-reported SA/DP rather than register data, with a risk of bias, e.g., recall bias (56-58).

1.3.1.1 Sickness absence and disability pension benefits in Sweden

The Swedish public SA insurance covers all individuals in Sweden from age 16 years, with income from work, unemployment benefits, or parental leave. Claims for benefits are assessed, determined and administered by the Swedish Social Insurance Agency (52). The first 7 days of a SA spell can be self-certified by the individual. After that a medical certificate from a physician is required. Sickness absence benefits can be granted to individuals from 16 years of age with an income from work or unemployment benefits, who, due to disease or injury, have a reduced work capacity. The work capacity is to be determined in relation to work demands of the claimant's job or other jobs at the labour market. The first day of a SA spell is an unreimbursed qualifying day. For employed individuals, day 2-14 usually are reimbursed by the employer as sick pay. When a SA spell exceeds 14 days, an individual can receive SA benefits through the Social Insurance Agency. Unemployed individuals are reimbursed by the Social Insurance Agency after the qualifying day, while self-employed can have a qualifying period of between 1 and 90 days. Sickness absence benefits covers 80% of lost income, up to a certain level (52).

Disability pension can be granted to individuals living in Sweden aged 19-64 years who, due to disease or injury have a long-standing or permanent reduction of their work capacity. Young adults, aged 19-29 can be granted temporary DP for such work incapacity or if not able to complete compulsory or upper secondary school studies in the ordinary time (59). From 1 July 2008, only permanent DP can be granted to individuals from the age of 30 years. (59). DP is compensated in part to a guaranteed amount depending on age and other factors, and in part through income-related additional coverage with up to about 65% of lost income up to a certain level. Sickness absence and DP can be reimbursed for full- or part-time, i.e., 100, 75, 50, or 25% of ordinary work hours (59).

There is a lack of studies investigating work capacity after road traffic crashes, in terms of SA and DP, in large study populations that include all types of injuries, while taking into account SA and DP prior to the crash. Furthermore, there are no studies on how PMI of all grades and DP are associated.

2 AIM

The overall aim of this thesis was to gain knowledge on SA, DP, and PMI, among individuals injured in passenger car crashes.

The specific aims of the two studies were to:

Study I: investigate the occurrence of already ongoing SA and DP, and of new SA spells exceeding 14 days, in general and for different injury diagnosis, among passenger car occupants receiving medical healthcare after being injured in a road traffic crash.

Study II: investigate SA, DP and PMI, among injured passenger car occupants two years after the crash, and how they are associated, accounting for sociodemographics, previous SA/DP and crash-related factors.

3 MATERIAL AND METHODS

3.1 DESIGN AND STUDY POPULATIONS

Both of the studies included in this thesis were explorative cohort studies using data from Swedish nationwide registers. Different populations were used in the two studies.

Study I was a population-based cohort study. It included all individuals aged 16-64 years who were living in Sweden on 31 December 2009, who in 2010 received in- or specialized outpatient healthcare due to injuries sustained as passenger car occupants in road traffic crashes (N=13,948). The age range 16-64 was chosen to have a population at-risk of SA, regarding age. The injured individuals were identified through the external causes of morbidity codes, V40-V49 (Car occupant injured in transport accident), of the Swedish version of ICD-10, registered by national healthcare services (60). To confirm that the healthcare visits were indeed due to incident car crashes, individuals who at any time during the three years prior to the date of the inclusion healthcare visit had been treated for a traffic-related crash injury were excluded (n=1520). Excluded were also those injured in non-road traffic situations (n=1887), and those who died from their injuries, defined as dead ≤ 30 days after the healthcare visit (n=99). Excluded were also those that neither had an injury diagnosis code nor the code Z04.1, "Examination and observation following transport accident" (n=895), as well as those with codes T90-T98 stating late effects (>1 year) of injury, indicating that the injury was not sustained in close temporal proximity with the healthcare visit (n=120). The final cohort thus comprised 9427 individuals. Prevalent SA and DP at the time of the health care visit, as well as incident SA was investigated, and associations of sociodemographic factors, and injury type with incident SA were assessed.

Study II was a prospective cohort study. Included were individuals injured as passenger car occupants reported to Folksam Insurance Group. All occupants injured in crashes between 2001 and 2013, and aged 17-62 years at the year of the crash were included. This age range was chosen in order to have a population at-risk of DP, regarding age-related eligibility, at the end of follow-up. Excluded were those who died from their injuries, defined as dead ≤ 30 days after the crash, or who had another crash during the two-year follow-up. This resulted in a cohort of 64,007 individuals. Prevalent SA and DP at the time of the crash, and SA and DP status at follow-up two years later, as well as determined PMI grade from the injuries were investigated. Associations of sociodemographic factors, SA status at inclusion, impact direction, car model year, and PMI grade with DP at follow-up were assessed. Furthermore, associations of sociodemographic factors, SA and DP status at inclusion, impact direction, car model year with subsequent PMI determined for the injuries.

Table 2. Overview of Study I and Study II

	Study I	Study II
Aim	To investigate occurrence of already ongoing SA and DP, and new SA spells exceeding 14 days, in general and for different injury diagnosis, among passenger car occupants receiving medical healthcare after being injured in a road traffic crash	To investigate SA, DP and PMI among injured passenger car occupants two years after the crash, and associations between PMI and DP, accounting for sociodemographics, previous SA/DP, and crash-related factors
Design	Register based cross-sectional population-based cohort study	Prospective cohort study
Data sources	LISA ¹ , National in- and specialized outpatient register, Cause of Death Register, MiDAS ²	Folksam injury database, LISA ¹ , Cause of Death Register, MiDAS ²
Study population; n	9427 (16-64 years, 48% women)	64,007 (17-62 years, 51% women)
Inclusion criteria	On 31 December 2009: Living in Sweden, aged 16-64 years. Receiving in- or specialized outpatient healthcare in 2010 for injuries sustained as passenger car occupants in a road traffic crash, no transportation related injury during three years prior to inclusion, not dead within 30 days of crash	Injured in passenger car crash between 2001 and 2013, reported to Folksam. No new crash within the 2-year follow-up period. Not dead within 30 days of crash. On 31 December the year before the crash: Living in Sweden, aged 17-62 years.
Outcome measures	SA >14 days	SA >14 days and DP two years after the crash. Determined PMI from the injuries
Factors included in the analyses	Sex, age, educational level, country of birth, marital status, type of living area, crash type, medical care, injury type	Sex, age, educational level, country of birth, marital status, SA/DP status at the date of the crash, crash impact direction, car model year, SA and DP 2 years after the crash, PMI grade determined from injuries
Statistical analysis	Descriptive statistics, logistic regression analysis	Descriptive statistics, logistic regression analysis

¹LISA: Longitudinal Integration Database for Health Insurance and Labour Market Studies, Statistics Sweden

²MiDAS: Micro Data for Analysis of the Social Insurance, Swedish Social Insurance Agency

3.2 DATA SOURCES

Both studies utilised de-identified microdata obtained from Swedish nationwide registers administered by Swedish authorities. Study II also included data from the injury database of the Swedish insurance company Folksam Insurance Group. Data from the different registers was linked on an individual level, using the ten-digit personal identity numbers assigned to all individuals living in Sweden (61).

3.2.1 Longitudinal Integration Database for Health Insurance and Labour Market Studies (LISA)

This register is administered by Statistics Sweden, and contains information on all individuals aged 16 or older and living in Sweden, recorded annually on 31 December (62). The register

has information on sociodemographic factors regarding demographics, education, employment and social security benefits, income, family.

In study I, LISA was used to identify all individuals 16-64 years old and registered as living in Sweden on 31 December 2009.

3.2.2 The National Patient Register

The National Patient Register is administered by the National Board of Health and Welfare, and contains information about in- and specialized outpatient healthcare. It does not include information from non-specialized outpatient care, i.e., primary care. Caregivers are required to register all healthcare encounters annually. Diagnoses are coded according to the Swedish version of the International Classification of Diseases (ICD). The quality of the register is considered high. For 99% of registered healthcare encounters, there is diagnosis code, and 98% of injuries have a stated cause (63).

In study I, this register was used to identify all individuals having visits to in- or specialized outpatient healthcare facilities during 2010, due to injuries sustained as occupants in passenger car crashes. Identification was possible through the external causes of morbidity codes of the ICD-10, which also made it possible to identify and exclude individuals with transportation related injuries three years prior to the inclusion healthcare visit.

3.2.3 Folksam Injury Database

Folksam Insurance Group is one of the largest Swedish insurance companies. The market share on road traffic insurance for vehicles is approximately 20% (64), and is considered representative of the general population. The Folksam injury database, contains information regarding individuals injured in crashes with vehicles insured with Folksam, e.g., sex, age, position in car, injury coded according to AIS, determined PMI grade from the injuries sustained in the crash. It also contains information regarding to the car and the crash, such as impact direction, and car model year.

In study II, the Folksam Injury database was used to identify individuals injured in road traffic crashes, as passenger car occupants, during the years 2001-2013.

3.2.4 Micro Data for Analysis of the Social insurance (MiDAS)

This register is administered by the Swedish Social Insurance Agency, and contains information on SA, DP and other benefits within the social insurance, regarding start and end date of spells, extent of spells, and diagnoses coded according to the ICD-10 (65).

3.2.5 The Cause of Death Register

The Cause of Death Register is administered by the National Board of Health and Welfare, and contains information on dates and causes of deaths among all individuals registered as Swedish residents (66).

3.3 EXPOSURE, COVARIATES, AND OUTCOME MEASURES

In the studies, different information describing the included individuals in terms of sociodemographics and already ongoing SA/DP was used. Further, information on crash-related factors, and in Study I also injury type and type of healthcare was used. The included sociodemographic, injury- and crash-related factors were selected based on their associations with SA, DP, and PMI that previous studies have reported.

3.3.1 Injury-related factors

3.3.1.1 Injury diagnosis and the Barell matrix

In Study I, diagnoses coded according to ICD-10 were obtained from the National Patient Register. A majority (79%) of the individuals had only one unique diagnosis code. For the remaining 21%, a selection was made to reach one code per individual. The following selection hierarchy was used: main diagnosis > secondary diagnoses, inpatient care diagnosis > outpatient care diagnosis, and injury diagnosis > other types of diagnoses. A modified form of the Barell matrix was used in order to create meaningful injury categorization. The Barell matrix classifies ICD-9-CM codes into 12 columns representing nature of injury and 36 rows representing body regions, assigning each code to a specific cell of the matrix (67). The ICD-10 codes from the National Patient Register were mapped into the matrix, and the ICD-10 code Z04.1, examination and observation following transport accident, was added. For the main analyses in this study, a categorization of 10 injury types was created. In an additional analysis, the Barell matrix categories for fractures to the torso, vertebral column and upper and lower extremities were used.

3.3.1.2 Medical care

In study I, medical care in relation to the crash, in terms of specialized outpatient or inpatient care, and length of inpatient care stay, was used in descriptive statistics. It was not used in logistic regression analyses, as it was considered to be on the causal pathway between injury and SA.

3.3.2 Sociodemographic factors

In both of the two studies, LISA was used to obtain sociodemographic information. The sociodemographic variables included in the studies were sex, age, educational level, country of birth, marital status. In study I, type of living area was also included. In both studies outcome variables were stratified on sociodemographic variables in descriptive analysis. In logistic regression analyses, sociodemographic variables were controlled for, but also used to examine differences for different sub-groups when assessing associations with the outcome variables.

3.3.3 Crash-related factors

In Study I, a variable for crash type was constructed based on the ICD-10 external causes of morbidity codes obtained from the National Patient Register. In Study II a variable for crash impact direction was constructed from Folksam injury database information. Information on the model year of the car was obtained from the Folksam injury database and categorised into five-year categories. Crash impact direction and model year was used to control for in the regression analyses, and to assess associations with DP two years after crash, and determined PMI from the injuries sustained in the crash.

3.3.4 Sickness absence and disability pension

In both studies, SA was defined as full- or part time spells lasting >14 days. In study I, individuals in the study population were identified through date of healthcare encounter rather than date of crash. However, the crash, the healthcare encounter, and the start of a SA spell, does not necessarily take place on the same day. Based on the distribution of start dates of SA spells in relation to the date of the healthcare encounter, *a new SA spell* was defined as a spell starting ± 4 days of the date of the healthcare encounter. Sickness absence spells that were ongoing already five days prior to, and DP that was ongoing at the date of, the

healthcare encounter, were considered as *already ongoing*, that is, that the patient was already on SA/DP when injured. Patients on part-time DP were still at risk for SA for the remaining percentage of working time, that is, if an individual was on DP for e.g., 25% of full-time he or she could be on SA for 25, 50, or 75% of full-time at the same time.

In study II, *already ongoing* SA and DP were defined as spells already ongoing at the date of the crash. Follow-up was defined as 365*2+6 days after the crash dates. The six extra days were added to allow for the possibility of leap year, and for the possibility of spells not starting on the exact day of the crash. *New SA* was operationalised as having a SA spell lasting >14 days at the date of follow-up. *New DP* was defined as DP ongoing at follow-up, or SA spells starting within 4 days of the crash and ongoing at follow-up, i.e., spells with a duration of ≥ 2 years. This definition was used to facilitate international comparison (53).

3.3.5 Permanent medical impairment

In study II, for occupants with a determined PMI due to their injuries from the crash, a total PMI grade for each individual based on his or her injuries was used. In the descriptive analysis, PMI was categorised: 0, 1-4, 5-9, 10-19, and ≥ 20 , or: no PMI and PMI $\geq 1\%$, depending on analysis. As independent variable in the logistic regression with DP at follow-up as outcome, PMI was categorised: no PMI, 1-4%, and $\geq 5\%$ no PMI, 1-4%, and $\geq 5\%$. As outcome variable in logistic regression analysis, PMI was categorized: no PMI and PMI $\geq 1\%$

3.4 STATISTICAL ANALYSIS

In study I, descriptive statistics were used to describe the study population as well as crash- and injury type, for all and stratified by sex. Descriptive statistics were also used to investigate the utilisation of medical care, prevalent SA and DP at the time of the crash as well as incident SA, for all, and stratified by age group and crash type. Crude and adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for incident SA were calculated with logistic regression analyses. In the regression models, occupants with already ongoing SA or full-time DP, i.e., not at risk, were excluded. Univariable analysis was used to assess the association between factors potentially influencing the outcome; those found to have a statistically significant association were included in the adjusted models. The variable sex was included in the adjusted models. A multivariable model using injury type categories was created, mutually adjusting for all included covariates. For the purpose of investigating specific diagnosis groups, a second multivariable model was created, including only individuals with a selected diagnosis of fracture to the torso, the vertebral column or the upper or lower extremities. The regression analyses were stratified into age, with categories 16-44 years, and 45-64 years old. Data processing and analyses were performed using IBM SPSS Statistics for Windows.

In study II, descriptive statistics were used to describe the study population, in total and stratified by sex. Proportions with already ongoing SA and DP at the time of the crash (inclusion date), as well as proportions with new SA at follow-up, and proportions with different grades of determined PMI were calculated. Descriptive analyses were also used to investigate SA and DP status at follow-up in relation to status at inclusion, for all and stratified by PMI. Logistic regression analyses were used to calculate crude and adjusted odds ratios (OR) and 95% confidence intervals (CI) for DP and PMI status, respectively, at follow-up. For each of these outcomes, a mutually adjusted multivariable model was constructed. Included as independent variables were the factors identified through the literature, that were available in the registers and found to have an association with the outcome in univariable

analysis. In the regression analysis with DP at follow-up as an outcome, occupants with DP at inclusion, i.e., not at risk, were excluded. In the regression analysis with PMI as an outcome, the whole cohort was included. Factors included in the regression analysis were assessed regarding association with the outcomes in univariable analysis; if the association was significant, they were included in the multivariable analyses. IBM SPSS Statistics for Windows was used for analyses.

4 RESULTS

4.1 STUDY I

In this cohort (n=9427), around half were women (48%), a similar proportion had high school as their highest education (48%), while a majority was born in Sweden (80%), and unmarried (70%). The most common type of living area was medium-sized cities (39%). *Sprains of the cervical spine*, including whiplash injuries, was the most frequent type of injury (27%), followed by *injuries to the head, face, and neck*, of other type than brain injuries, sprains of the cervical spine, and injuries to the vertebral column and spinal cord (24%).

In the cohort, 898 individuals (10%) had a new SA following the crash, while 834 (9%) already had an ongoing SA spell or were on full-time DP at the time of the crash. The median duration of new SA spells was 44 net days. A higher proportion of the women than the men had already ongoing SA or DP, while the proportions with new SA were similar. An age-related trend was found both for ongoing SA and DP, and new SA spells, with higher proportions with increasing age.

Crash types, coded according to ICD-10 external causes of morbidity codes were not associated with new SA and were thus not included in the multivariable analysis. Results from the multivariable logistic regression analysis are shown in Table 3 (for crude results, see the appendix with Study I). In the younger age group, 16-44 years old, individuals with high school as their highest educational level were more likely to have a new SA compared to those with college or university education, while those with elementary school were found less likely. In the older age group, 45-64, educational levels equivalent to elementary school and to high school were both associated with higher ORs of new SA. In the younger age group, individuals born outside of Europe, and those married were found more likely to have a new SA, compared to individuals born in Sweden and individuals not married, respectively. No statistically significant associations between country of birth and marital status were found in the older age group of 45-64 year olds. No association was found between sex and new SA. The strongest associations with new SA was found for injury types. In both age groups, individuals with injuries to the spine or spinal cord were the most likely to have a new SA, the reference group being sprains of the cervical spine. In the younger age group, injuries to the lower extremity was the injury type with the second highest OR. In the older age group, this was traumatic brain injuries other than concussion.

Table 3. Mutually adjusted odds ratios (OR) with 95% confidence intervals (CI) for new sickness absence (SA) >14 days, for all, and stratified by age

	All (n=8593) Adjusted OR (95% CI)	Age 16-44 (n=6709) Adjusted OR (95% CI)	Age 45-64 (n=1884) Adjusted OR (95% CI)
<i>Sex</i>			
Men (n=4578)	Ref	Ref	Ref
Women (n=4015)	1.1 (0.95-1.27)	1.13 (0.94-1.35)	1.02 (0.79-1.33)
<i>Level of education (years)</i>			
College/University (≥ 12) (n=2068)	Ref	Ref	Ref
High school (10-12) (n=4142)	1.41 (1.18-1.70)	1.45 (1.15-1.83)	1.39 (1.02-1.89)
Elementary (≤ 9) (n=2383)	0.76 (0.60-0.95)	0.66 (0.50-0.87)	1.54 (1.04-2.28)
<i>Country of birth</i>			
Sweden (n=6946)	Ref	Ref	Ref
Europe other than Sweden (n=303)	1.05 (0.72-1.52)	1.11 (0.64-1.91)	0.75 (0.45-1.26)
Rest of the world (n=1344)	1.29 (1.07-1.56)	1.31 (1.04-1.65)	1.22 (0.86-1.74)
<i>Married</i>			
No (n=6086)	Ref	Ref	Ref
Yes (n=2507)	1.63 (1.39-1.90)	1.71 (1.39-2.10)	0.95 (0.73-1.23)
<i>Injury</i>			
Sprain of the cervical spine (n=2281)	Ref	Ref	Ref
Concussion (n=339)	2.66 (1.80-3.93)	2.34 (1.46-3.74)	3.97 (1.91-8.25)
Other traumatic brain injury (n=83)	6.99 (4.04-12.08)	5.07 (2.45-10.48)	14.68 (5.80-37.17)
Other head, face and neck (n=2091)	1.18 (0.90-1.54)	0.93 (0.67-1.28)	2.14 (1.27-3.59)
Spine (Vertebral column and spinal cord) (n=392)	8.64 (6.45-11.57)	6.32 (4.42-9.05)	17.32 (9.85-30.48)
Torso (n=1277)	3.03 (2.36-3.89)	2.53 (1.88-3.41)	4.50 (2.75-7.37)
Upper extremity (n=906)	4.51 (3.49-5.82)	4.26 (3.17-5.74)	5.28 (3.15-8.84)
Lower extremity (n=527)	5.82 (4.39-7.73)	5.64 (4.08-7.81)	6.73 (3.75-12.05)
Other and unspecified (n=125)	2.06 (1.12-3.79)	1.98 (0.99-3.96)	2.49 (0.69-8.97)
Observation and complications (n=572)	0.93 (0.60-1.45)	0.81 (0.48-1.38)	1.38 (0.62-3.04)

4.2 STUDY II

In this cohort (n=64,007), 51% were women, a majority (78%) was born in Sweden, was unmarried (67%), and had high school as highest achieved education (53%). At the time of the crash, 5755 (9%) were already on DP, and 2755 (4%) were on an already ongoing SA spell. At the two-year follow-up, 7409 (12%) were on DP and 5237 (8%) were on a SA spell. However, SA and DP at follow-up was found highly associated with already ongoing SA and DP at the time of the crash. Out of the 55,497 individuals with neither DP nor SA ongoing at the time of the crash, 1099 (2%) were found to have DP and 3846 (7%) to have SA at follow-up.

A total of 5035 (8%) of the individuals had a determined PMI due to their injuries. Among individuals with a PMI, the median PMI grade was 4% for both women and men, 5% for those with DP at follow-up, and 3% for those with no DP at follow-up (Not in table). Among those not already on DP at the time of the crash, the proportion of individuals with DP at follow-up increased with increasing PMI grade (**Figure 2**). Out of those not on DP at the time

of the crash that had a determined PMI, the median PMI grade was 6% for those on DP at follow-up, and 3% for those not on DP at follow-up (Not in table).

Results from the multivariable logistic regression analyses are shown in Table 4 (for crude results, see the appendix with Study II). For DP at follow-up as outcome, the highest OR was found for already ongoing SA at the date of the crash. Furthermore, individuals with a determined PMI were more likely to have a DP at follow-up, compared to those with no PMI, with ORs being higher for higher PMI categories. Associations were also found between sociodemographic factors and DP at follow-up. An association was found with age, the ORs were higher in older age groups, compared to those 17-24 years old. Individuals with elementary or high school as their highest level of education were more likely to have DP at follow-up, compared to individuals with college or university education. Compared to individuals born in Sweden, those born outside of Sweden were more likely to have DP at follow-up. Crash-related factors were also associated with DP two years after the crash. Individuals injured in cars with model year 2000 or older were more likely to have DP at follow-up, compared to those injured in cars with model years 2006-2010. Being injured in a rear impact was associated with a lower OR compared to frontal impacts.

For determined PMI due to the injuries sustained in the crash as outcome, associations were found with sociodemographic variables. Women were more likely than men to have PMI, individuals ≥ 25 years old were more likely than those aged 17-24. Individuals with lower levels of education had higher ORs compared to individuals with college or university education. Being born outside of Sweden was also associated with a higher OR for PMI, compared to those born in Sweden. Associations were also found between crash-related factors and PMI. Individuals injured in rollover crashes were more likely to have a PMI, compared to individuals injured in frontal crashes, while rear and side impact directions were associated with lower ORs. Model year of the car was associated with both DP and PMI. The older the car, the higher OR, compared to the reference category with model years 2006-2010.

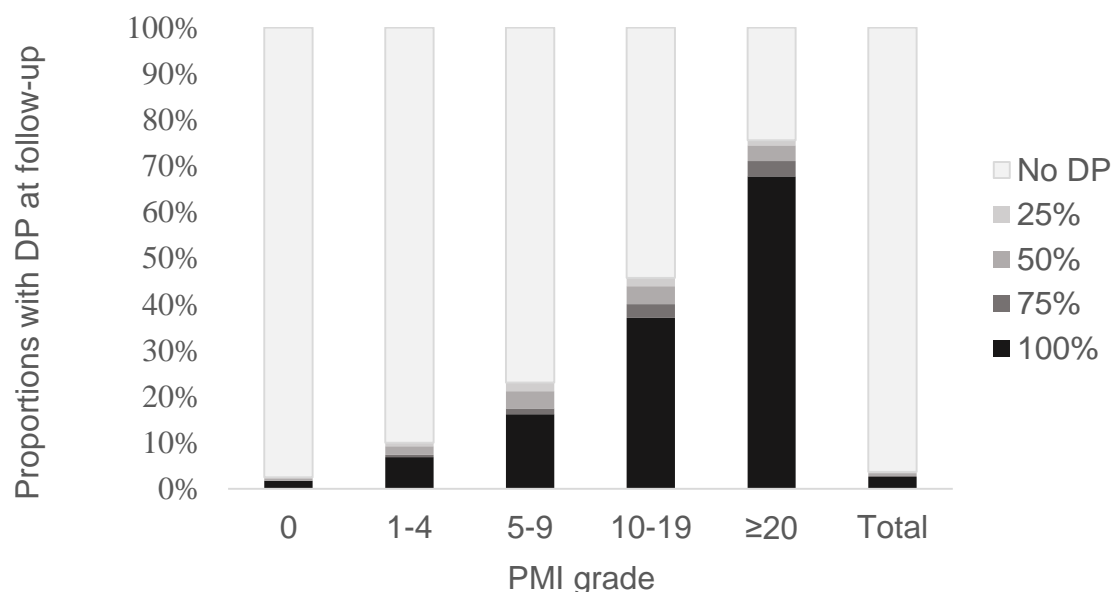


Figure 2. Proportion (%) of injured car occupants on disability pension (DP) two years after the crash date, stratified by permanent medical impairment (PMI) grade, among those not on DP at the date of the crash (n=62,876). DP grade (100, 75, 50, 25% of ordinary working hours) is shown by different colors.

Table 4. Mutually adjusted odds ratios (OR) with 95% confidence intervals (CI) for disability pension (DP) at two-year follow-up after a car crash (occupants already on DP at crash excluded), and permanent medical impairment (PMI), respectively.

	DP at two-year follow-up (n=58,252)		PMI ≥1% (n=64,007)	
	n	Adjusted OR (95% CI)	n	Adjusted OR (95% CI)
<i>Sex</i>				
Men	29,047	Ref	31,226	Ref
Women	29,205	1.11 (1.00-1.23)	32,781	1.24 (1.17-1.32)
<i>Age (years)</i>				
17-24	16,290	Ref	16,446	Ref
25-34	13,944	1.29 (1.07-1.56)	14,354	1.39 (1.27-1.53)
35-44	12,461	2.12 (1.76-2.54)	13,650	1.48 (1.34-1.63)
45-54	9926	2.75 (2.28-3.32)	11,875	1.47 (1.32-1.63)
55-62	5631	3.82 (3.12-4.68)	7682	1.40 (1.25-1.58)
<i>Level of education (years)</i>				
College/University (>12)	13,045	Ref	13,877	Ref
High school (10-12)	30,819	1.49 (1.30-1.72)	33,955	1.30 (1.20-1.40)
Elementary (≤9)	14,388	2.09 (1.78-2.46)	16,175	1.30 (1.19-1.43)
<i>Country of birth</i>				
Sweden	45,685	Ref	49,880	Ref
Europe other than Sweden	5292	1.51 (1.30-1.76)	6151	1.29 (1.17-1.41)
Rest of the world	7275	1.35 (1.16-1.56)	7976	1.25 (1.14-1.36)
<i>Married</i>				
No	39,674	Ref	42,718	Ref
Yes	18,578	1.10 (0.98-1.23)	21,289	1.08 (1.01-1.16)
<i>SA at inclusion</i>				
No	55,497	Ref	61,252	Ref
Yes	2755	39.16 (34.89-43.95)	2755	1.40 (1.23-1.58)
<i>DP at inclusion</i>				
No		<i>n.a.</i>	58,252	Ref
Yes			5755	1.22 (1.11-1.35)
<i>Car model year</i>				
2006-2010	1984	Ref	2161	Ref
2001-2005	6262	1.48 (0.96-2.29)	6978	1.61 (1.26-2.06)
1996-2000	13,133	1.88 (1.25-2.85)	14,539	1.95 (1.54-2.46)
1991-1995	12,416	2.51 (1.66-3.79)	13,682	2.66 (2.11-3.35)
1990 or older	14,447	2.74 (1.82-4.13)	16,003	3.36 (2.67-4.23)
Unknown	10,010	1.25 (0.81-1.92)	10,644	1.27 (1.00-1.62)
<i>Crash impact direction</i>				
Frontal	20,332	Ref	22,300	Ref
Rear	21,462	0.86 (0.76-0.97)	23,535	0.92 (0.85-0.98)
Side	9877	0.99 (0.86-1.15)	11,017	0.87 (0.79-0.94)
Rollover	3461	1.06 (0.85-1.32)	3693	1.41 (1.26-1.59)
Unknown	3120	1.15 (0.93-1.42)	3462	1.04 (0.91-1.18)
<i>PMI grade (%)</i>				
No PMI	53,825	Ref	58,972	<i>n.a.</i>
1-4	2653	4.24 (3.57-5.04)	3074	
≥5	1774	27.44 (23.88-31.52)	1961	

5 DISCUSSION

In these two exploratory studies, it was found that 10% of injured car occupants had a SA spell >14 days following the crash. At two years after the crash, 8% were on a SA spell >14 days, while 12% were on DP. A PMI was determined for 8% of the injured individuals in Study II. The proportions with already ongoing SA or DP at the time of the crash, were 9% in Study I and 13% in Study II. The populations of the two studies differed somewhat. Study I included individuals 16-64 years old with in- or specialized outpatient healthcare in 2010 due to injuries sustained in a passenger car crash, while in Study II all those reported to Folksam Insurance Group as injured in a passenger car crash during 2001 to 2013, when in age 17-62, were included. Sickness absence following the crash was found to be highly associated with injury type, occupants with injuries to the spine being the most likely to have a new SA. A strong association was found between already ongoing SA/DP and SA/DP at the two-year follow-up. Proportions with DP two years after the crash were higher in higher PMI grade categories. When controlling for other factors in multivariable regression models, there was a strong association between already ongoing SA at the time of the crash and DP two years after the crash, as well as between PMI grade and DP two years after the crash. Sociodemographic factors, car model year, and impact direction were also associated with DP and PMI.

5.1 DISCUSSION OF RESULTS

In Study I, 10% of the individuals injured as occupants in passenger car crashes had a new SA spell >14 days following the crash. Two previously published studies investigating incident SA for all types of injuries and severity grades showed higher SA rates, however, they also included short-term SA, that is SA spells ≤ 14 days (68, 69). In general, the majority of SA spells are short-term, about half of all SA spells have ended within seven days and only about 2% become longer than 90 days (70, 71). In Study II, 8% of the injured individuals had a SA spell >14 days at the two-year follow-up. Interestingly, in Study II, within the group with no ongoing SA or DP at the time of the crash, 7% had SA >14 days at the follow-up, which is almost as high as the proportion with SA following the crash in Study I. However, because investigating SA diagnoses were not in the scope of Study II, it cannot with certainty be discriminated to what extent this SA is due to the injuries sustained in the crash, and to what extent this is due to other morbidity of the individuals. This is something for future studies to examine.

5.1.1 Improvements of the road transport system

The strongest risk indicator for PMI in Study II was model year of the passenger car, which was also found associated with DP two years after crash. The benefits of modern car safety have been proved in analysis of real-life data. Standardised consumer crash tests have led to significant improvements in vehicle crashworthiness (72-74). Since the late 1990s more advanced concepts aimed at reducing the risk of whiplash have been introduced on the market (48). When comparing car drivers seated in cars introduced on the market during 1980-84 with drivers seated in modern cars from 2005-09, the proportion of drivers with PMI due to whiplash injuries had dropped by over 50% (48). Furthermore, modern safety system such as Electronic Stability Control that was introduced 1998 has been shown to effectively reduce the injury risk, especially serious and fatal injuries (45-47). For future studies there will be even more safety systems to be taken into account. For instance, Autonomous Emergency Braking, another modern car safety system aiming at avoiding or mitigating

crashes that has been shown to dramatically reduce road traffic casualties (75), and this will thereby affect the number of car occupants with long-term consequences. Also, seat-belt reminders in modern vehicles have been shown to increase seat-belt use (76), and seat-belt use has been shown to dramatically reduce the risk of getting injured (77). Seat belt use was not considered in the present thesis as this information was not available. However, a previous study showed that only 10% of the occupants in crashes with RPMI were not using the seat belt (78). Furthermore, seat-belt use has been shown to result in a reduction of mean lost days of work after a motor-vehicle crash (79). The effect of improved car safety could be seen in Study II, as occupants injured in cars with older model years, implying less modern car safety features, were more likely to have a DP two years after the crash, as well as having a PMI determined for their injuries, compared to those injured in newer cars. Over the years, development has also been taking place in other areas affecting consequences of traffic injury. Improvements in road safety such as the implementation of median- and side barriers and roundabouts have been shown effective in reducing the crash severity (80, 81). Changes in assessment practice of PMI have also had an effect on the prevalence and incidence of these consequences of traffic injuries (48). These factors were out of the scope of this thesis, further studies would be required to assess their association with DP and PMI.

5.1.2 Already ongoing sickness absence and disability pension when the crash occurs

In Study II, a high association was found between already ongoing SA and DP at the time of the crash and SA at the two-year follow-up. A third of the group already on SA or DP at the time of the crash had SA at the follow-up. There might be several explanations for this association, e.g., a decrease of work capacity due to worsening of existing medical conditions, or a vulnerability for consequences of traffic-related injuries. Among those on DP or on SA at the time of the crash, 91% and 39%, respectively, had DP two years after the crash date, while this proportion was only 2% among those with no ongoing SA/DP at the time of the crash. A transition of SA into DP is expected for cases of long-term work incapacity due to the injury. In Study II, SA starting at the crash and that was still ongoing at follow-up (>2 years) was defined as DP. In fact, in the regression analysis, where those already on DP were excluded, already ongoing SA at the date of the crash was the factor with the strongest association with DP at follow-up. This already ongoing SA showed the presence of existing morbidity that caused work incapacity prior to the crash. A previous study found self-reported pre-injury chronic disease to be associated with not having returned to work two years after sustaining an injury in a motor vehicle crash (82), while only one of two studies on the association between self-assessed pre-injury health and return to work after motor vehicle crashes showed an association (82, 83). Among individuals with whiplash injuries, neck disability prior to the crash has been found associated with duration of compensation for loss of earnings of more than two years (84), and individuals with granted compensation for loss of earnings due to the whiplash injury have been found to use more healthcare the year prior to the injury, compared to individuals with no granted compensation (85).

Very few studies include history of SA and DP when studying consequences of traffic injury. One study of individuals with whiplash injuries found that a history of SA prior to the crash was associated with both considerable neck pain and a negative change in provisional status, defined as going from self-supporting or unemployed to temporary or permanent health-related benefits, or going from temporary to permanent health-related benefits, one year after the crash (86). Another study found that SA but not DP prior to the crash was associated with

subsequent chronic whiplash (87). The results of the studies in this thesis together with these previous studies imply that history of SA and DP and/or ongoing SA and DP at the crash, should be considered when studying consequences of traffic injury.

5.1.3 Sociodemographic factors

In the two studies, sociodemographic factors were found associated with SA and DP. The proportions of individuals with new SA following the crash increased with age, and the ORs of having a DP at follow-up was higher with increasing age. The risk of being injured in motor vehicle crashes has been found higher among those of older age in many studies (88-91). Higher age has also been associated with work incapacity after road traffic injury (92, 93). In study II, occupants aged 45-64 were almost three times, and those aged 55-62 almost four times, more likely to be on DP two years after injury as the reference group of those 17-24 years old. In the older age group (45-64 years old) in study I, injuries to the spine and spinal cord, and traumatic brain injuries of other type than concussions stand out especially, with very high ORs for SA following the crash, compared to the reference category sprains of the cervical spine. A previous study has shown that car occupants ≥ 46 years old have higher risk of AIS2+ spinal injuries (94). Furthermore, these injuries have not decreased over the recent decades, but rather increased (95). This warrants further studies on consequences of spinal injuries in this age group, and how to effectively prevent them. Age-optimized safety systems in cars and road infrastructure, and age-focused interventions to return to work might prove beneficial preventive measures. From a work-capacity perspective, car safety systems could be an effective way of reducing consequences from injuries sustained in car crashes. Few examples of such car safety systems, that target these injuries currently exists (96).

Furthermore, individuals with lower education were more likely to have a new SA spell following the crash, to be on DP two years after the crash, as well as having a determined PMI, compared to those with college or university education. An exception was individuals aged 16-44 with elementary school as their highest educational level; they were less likely to have a new SA spell following the crash. This exception from the trend may be due to that a lower proportion in this group have passed from education to paid work, thus the proportion eligible for SA would be lower. There may be many reasons for the associations between low educational level and SA/DP, previous studies have however shown that lower educational levels are associated with higher risks of being injured in car crashes (97, 98). Previous studies of return to work after injuries from motor vehicle crashes, have presented heterogeneous results regarding the associations with education and occupation, where some studies have found an association (83, 99, 100), others have not (82, 101). In the younger age group in Study I, individuals born outside of Europe were more likely to have a new SA spell. In Study II, individuals born outside of Sweden were more likely than individuals born in Sweden to have DP at follow-up as well as a determined PMI. One possible explanation is that recently immigrated individuals may have less cultural safety awareness compared to those born in a Nordic country where such awareness is high in international comparison (102). Seat-belt-use rate can be taken as an example, varying widely between countries even where it is mandatory by law (6). Identifying vulnerable groups is important for targeting interventions that could prevent serious injury, e.g., by increasing safety awareness, and for adopting just and effective insurance compensation policy. However, more knowledge is warranted to clarify the associations between factors related to education, income and SA/DP.

5.1.4 Permanent medical impairment and disability pension

While the majority of individuals in the study population of Study II did not have DP at follow-up, the proportion with DP, however, increased with increasing PMI grade. When controlling for other factors in a multivariable logistic regression model, the association between PMI grade and DP was confirmed. A previous study with a study population of individuals with PMI grades $\geq 10\%$ also found that individuals with higher PMI were more likely to be granted DP after road traffic injury (103). In the study population of Study II, less than one percent had a PMI $\geq 10\%$. Comparison of the two studies is complicated by the fact that the two study populations differ. Furthermore, the difference in time between the inclusion to the previous study and Study II, result in changes having occurred in assessment practice of PMI (48). However, both studies infer an association between PMI and DP, in Study II this inference was based on PMI of all grades. The fact that, among those not already on DP at the time of the crash, PMI grade has a very strong association with DP status two years after crash would suggest that PMI as a measurement capture long-term consequences of road traffic injury also in terms of work incapacity. Among individuals with no ongoing DP at the time of the crash, already at PMI 5-9% one in four occupants have a DP two years after the crash. At PMI 10-19%, close to half have a DP, reaching three in four for those with a PMI $\geq 20\%$. The proportions with PMI $\geq 10\%$ is however very small. In Sweden the definition of serious injuries is defined as injuries with a RPMI of $\geq 1\%$. This is aimed to reflect long-term consequences of injuries. The results from this thesis indicate that injured car occupants with a determined PMI $\geq 5\%$ were 27 times more likely to be on DP two years after the crash, compared to those with no PMI. Therefore, it could be discussed if PMI $\geq 5\%$ is a more desirable level to reflect health loss, both in terms of biomedical and work capacity consequences. From the perspective of work capacity, based on the results from Study II, a low proportion of injured occupants with a PMI of $\geq 1\%$ would have a DP two years after the crash, while a target of PMI of $\geq 5\%$ would result in a larger proportion with DP.

More research is however needed to gain more knowledge on who with a certain PMI grade do get SA/DP as a result of their injury, and who does not. Future studies should, therefore, include injury diagnoses as well as SA and DP diagnoses.

5.2 METHODOLOGICAL CONSIDERATIONS

The main strengths of the two studies relate to the use of high quality Swedish nationwide register data, which strengthens the validity of the studies in several ways. The validity of a study pertains to the accurateness of the inferences that are being made, either concerning the population that the inferences concern (internal validity) or how the inferences can be generalized to the general or other populations (external validity) (104). The main factors influencing the internal validity are confounding, selection bias, and information bias.

Selection bias is when the procedure used to select participants creates a selection that is not representative of those theoretically eligible for participation, regarding the relation between exposure and outcome (104). Both studies in this thesis include all eligible (regarding age, year of crash etc.) individuals from the respective population, which in Study I was Swedish residents, and in Study II the Folksam Injury Database over reported injuries sustained in car crashes. This minimises the risk of selection bias.

Information bias is caused by measurement errors in the information required, which may lead to misclassification (104). If the misclassification of a variable is dependent on other variables, it is a differential misclassification, and may lead to over- or underestimation of

associations between exposure and outcome. If the misclassification is random, it is a non-differential misclassification, and may lead to a dilution of the estimate of association. By using data from high-quality registers with high coverage (66, 105, 106), the risk of misclassification is reduced. However, some of the variables had missing information, or was coded as unknown. The variable Crash type in Study I had a 23% proportion of cases coded as 'Unspecified traffic accident'. In study II, Car model year was unknown in 16.6%, and Crash impact direction in 5.4% of the cases. It is possible that having more detailed information on these cases, would change the estimates of association to some extent, however limited, between these variables and the outcome variables. The fact that these studies identified occupants already on SA/DP at the time of the crash is a strength of this study, and is something that has rarely been done in previous studies, as it reduces the risk of misclassification, and also selection bias since those not at risk could be excluded from analyses where needed.

The outcomes of the two studies, SA>14 days, DP, and PMI all have to be certified by a physician to be granted. The injury diagnoses used in Study I were also certified by physicians. This means that the risk of misclassification is substantially lower than if these variables would be, e.g., self-reported. However, selecting one injury diagnosis per individual can be seen as a limitation and a potential source of misclassification. The selection process may not have succeeded in pinpointing the diagnosis relevant for the SA. Furthermore, the effects of multi-trauma have not been assessed. However, this affects only a smaller group, as the majority (79%) had only one unique diagnosis.

In Study I, the crash date was not known, only the date of the healthcare visit due to the injuries sustained. To minimize misclassification of SA-status, this was handled by defining new SA as spells starting ± 4 days of the date of the health care visit, and ongoing SA and DP as spells starting ≥ 5 days prior to the health care visit. These cut-offs were based on distribution of start dates in relation to the dates of the health care encounters in the study population. Furthermore, to avoid including individuals having healthcare visits due to injuries from older crashes, individuals treated for transportation-related injuries at any time during a period of 3 years prior to inclusion were excluded.

Out of all identified occupants injured between 2001-2013 in Study II, a small proportion (5%) had more than one crash during this period. In this study, only the first crash was included. Furthermore, those with a new crash within two years of the first (2%) were excluded. This decreases the risk of DP and PMI at follow-up being affected by injuries from more than one crash. However, individuals may have had subsequent crashes were they were covered by other insurance companies, as well as other morbidity that affects DP status at follow-up. To minimize this risk, the follow-up period was limited to two years.

A confounding factor affects the association between exposure and outcome. It is associated with both the exposure and the outcome, while not itself being an effect of either one of them, and it is not a step in the causal pathway (104). The use of linked data from several registers, rendered it possible to control for several potential confounders, such as sociodemographic and crash-related factors. It is however possible that there may be confounding from factors not considered. Even so, the potential effect of residual confounding is considered to be limited, as the major contributing factors in the regression analyses were injury type in Study I, and already ongoing SA at the time of the crash in Study II, with the associations for remaining factors not being as strong.

Regarding external validity, Study I was based on the total Swedish population, including all those receiving healthcare during 2010 due to injuries from passenger car crashes. The results are thus directly applicable to the Swedish general population.

In Study II, the study population was identified from the Folksam Injury Database which is based on traffic injuries reported to Folksam Insurance Group: This company have an approximately 20% market share of the mandatory traffic insurance in Sweden (64), and the composition of this share is considered representative of the Swedish general population. This assumption is strengthened by the fact that the study population of Study II is very similar to the study population of Study I regarding the distribution of sociodemographic factors of the participants. The study population of Study II is somewhat older, have a higher proportion of individuals from Europe outside of Sweden, a lower proportion from the rest of the world, and a lower proportion of married individuals, compared to Study I, but the differences are small. The fact that the motor vehicle insurance is mandatory renders claims data representative of all injured. Furthermore, using this data allows to examine the whole spectrum of injuries, also those cases where the injured did not visit healthcare services.

For both Study I and II, generalisation of results to other populations can be done, while taking possible differences in factors such as social insurance systems and traffic injury reporting into consideration.

6 CONCLUSIONS

Among injured passenger car occupants, for 10% of those at risk for SA, the crash resulted in a new SA spell. Nine percent of the injured passengers already had an ongoing SA spell or were on full-time DP. The odds of having a new SA varied considerably with injury type. Car occupants with injuries to the spine or spinal cord were most likely to have a new SA. Among individuals aged 16-44, the second most likely injury type to result in a new SA was injuries to the lower extremities, while among individuals in ages 45-64, traumatic brain injuries other than concussion was the second most likely injury type. From a work capacity perspective, these injury types need to be addressed further to prevent consequences related to unacceptable health loss.

Higher proportions of car occupants with already ongoing SA and DP at the time of the crash, had SA and DP at two years after the crash date, compared to those not already on SA or DP, where 2% had DP, and 7% had SA at two years after crash. Already ongoing SA at the time of the crash was found to be the factor with the strongest association with DP at follow-up. Research on SA and DP as a consequence of traffic injury should therefore take this factor into consideration.

Eight percent had a determined PMI due to their injuries from the crash. Of those not already on SA or DP at the crash date, 15% with a determined PMI had DP compared to 1% of those without a determined PMI. There was a strong association between PMI grade and DP at two-year follow-up, among those not already on DP at the time of the crash, which remained when controlling for other factors. Occupants with a $\text{PMI} \geq 5\%$ were 27 times more likely to have a DP, compared to those with no PMI. Model year of the car, as a proxy for car safety level, was associated with both DP and PMI, ORs increased with increasing age of the car. These findings indicate that both DP and PMI can be used to measure long-term effects of road traffic injuries. From a work capacity perspective, a $\text{PMI} \geq 5\%$ better captures consequences of such injuries, in terms of DP two years after the crash, compared to the current Swedish definition of serious injury of $\text{PMI} \geq 1\%$.

7 RESEARCH SUGGESTIONS

The research is still very limited regarding SA, DP, and PMI at and after a traffic injury. The two studies in this thesis used an explorative approach to investigate the occurrence of already ongoing SA and DP at the time of the crash, new SA spells and future SA, DP, and PMI. More in-depth analyses are needed, including, e.g., information on SA, DP, and PMI diagnoses as well as about trajectories of SA and DP in the years following the crash.

Some injuries might, for example, not result in longer SA spells, but in shorter recurrent episodes. More research on the patterns of SA and DP due to different diagnoses are, therefore, warranted. These studies should be prospective and have long follow-up periods to be able to study changes over time. Gaining knowledge on the associations of specific injury types and these outcomes is important, not least from a prevention perspective.

The strong association between PMI grade and DP two years after the crash date should be studied more in-depth. Future studies should also include further information, e.g., on injury diagnoses, to be able to investigate who with a specific PMI grade also have a DP, and who does not.

The findings of the two studies in this thesis show the importance of identifying individuals with ongoing SA and DP at the time of the crash, and take this into consideration in analysis. There are also other factors that might be fruitful to include in future studies, such as age, since age was associated with both DP and PMI. Moreover, in the two studies of this thesis, education was associated with SA and DP after the crash. Being a proxy for income, the association between these factors and SA and DP is of interest to study further. Also, to widen the knowledge on long-term consequences of injuries sustained in car crashes, it would be of interest to take other health-related factors into consideration, such as healthcare and medication after the crash.

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